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ABSTRACT

Part of the Understanding Our Environment project that is designed to engage students in investigating specific environmental problems through concrete activity and direct experience, this unit contains a role-play activity in the form of a public inquiry into the cause of a fish kill on a river that runs through the fictional town of Oakwood. A variety of past and present, actual and potential problems are suspected, and the need for remedies is considered. Students represent the interests and concerns of townspeople and of special groups and in the process learn to appreciate the complexity of environmental issues. Objectives include: identifying a variety of possible causes of freshwater pollution; considering the impact of human activities on a waterway; learning about various aspects of water use, water quality, and water pollution; learning about water conservation and wastewater treatment; engaging in problem solving, analysis, and debate; considering the roles and responsibilities of citizens and businesses; developing an awareness of the different perspectives that are brought to environmental issues; experiencing the need to consider costs, risks, and benefits in attempting to solve problems; and recognizing the importance of accurate information and an informed citizenry in protecting and improving the environment. (JRH)

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UNDERSTANDING OUR ENVIRONMENT

SO 025 801

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WATER
LAND
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PEOPLE
CHALLENGE

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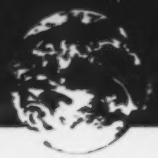

CHALLENGE

Clean Water Challenge
A Role-Play Activity

This publication is dedicated to Dr. Alan L. McClelland for his many years of devoted work at DuPont, in the government, and in the community to develop and educate people of all ages in mathematics, engineering, and chemistry. His commitment to advancing the understanding of the sciences has influenced thousands of lives and careers around the world.

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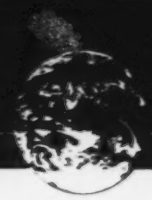

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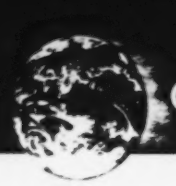


CHALLENGE : CONTENTS

Unit Summary 4

Front-Page Story 5

Teacher's Notes

The Clean Water Challenge 6

The Inquiry 7

Results of the Inquiry: Sample Answers 10

Further Analysis 12

Materials for the Role-Play Activity

Plan of the Oakwood Area 16

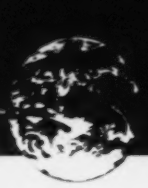
Cast List 17

Five Role Briefs: Five Points of View 18

Role Brief: The Expert 28

Public Inquiry Fact Sheet 31

Technical Supplement 32



What Caused the Mysterious Fish Kill?

This extended role-play activity takes the form of a public inquiry into the cause of a fish kill on a river that runs through the fictional town of Oakwood. A variety of past and present, actual and potential problems are suspected, and the need for remedies is considered. Students represent the interests and concerns of townspeople and of special groups and in the process learn to appreciate the complexity of environmental issues.

Objectives

- Identify a variety of possible causes of freshwater pollution. Consider the impact of human activities on a waterway. Learn about various aspects of water use, water quality, and water pollution.
- Learn about water conservation and wastewater treatment.
- Engage in problem solving, analysis, and debate.
- Consider the roles and responsibilities of citizens and businesses.
- Develop an awareness of the different perspectives that are brought to environmental issues.
- Experience the need to consider costs, risks, and benefits in attempting to solve problems.
- Recognize the importance of accurate information and an informed citizenry in protecting and improving the environment.

Kwood Herald FINAL

Established 1865

MYSTERY FISH KILL

Hundreds of dead fish have again been found in the Stag River. Local fishing club members are furious. "This is the third time we have restocked the river–something has got to be done," said Stanley O'Brien, an officer of the local fishing club. "It must be someone letting chemicals or something get into the river."

Police warned parents not to let their children play near the river until the cause of the incident is determined, in case there are toxic chemicals in the water. A government spokesperson said the incident is being investigated. She added that fish kills often occur in slow-moving water that has low oxygen content. "This is especially likely to happen in warmer weather," she said.

When asked to comment, local farmer Jane Grant, whose land adjoins the river, said she is an organic farmer and has not used any pesticides in over five years.

The old mill at Oakwood

Mill Reopens

The old mill at Oakwood Bridge has been restored and will be open to the public daily, starting July 25. There will be demonstrations every Wednesday at 2:00 p.m. Stoneground corn meal will be on sale at the museum shop. A new picnic area adjoins the museum.

LATE NEWS

TANKER OVERTURNS

There was a major accident on Route 94 late last night. A milk tanker traveling westbound overturned at Oakwood Bridge, and milk flooded all four lanes of the highway. A 2-mile tie-up lasted for 45 minutes, until firefighters finished hosing down the highway.

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The Clean Water Challenge

The Clean Water Challenge is intended as a culminating activity following the study of some or all of the other units. It is particularly recommended as a follow-up to the Water unit.

In this role-play activity, students investigate the sudden, mysterious death of hundreds of fish in a river near the fictional town of Oakwood. The incident is introduced through a front-page article in the local paper, *The Oakwood Herald*. The students' task is to conduct a public inquiry to determine the cause of the fish kills and recommend a course of action.

The town council members and citizens hear the testimony of townspeople whose work and leisure activities are tied to the river. All these roles are filled by students. Through role-playing, students experience some of the dilemmas and conflicts that are a part of environmental issues. As in real-life debate, emotions and prejudices may run strong.

In the course of the inquiry, the students evaluate the proposed solutions to various potential pollution problems that have been identified. At the conclusion, the whole class analyzes some aspects of the debate in greater depth.

The Clue

A clue to the real cause of the fish kill is given in the newspaper. Following an accident on the highway, milk from an overturned tanker truck was hosed into the river. The decomposition of milk, which is an organic substance, requires oxygen. Milk can also alter the river's acidity. It was the spilled milk that, by creating demands on the dissolved oxygen in the water, caused the fish to die from lack of oxygen.

The crash occurred at night. By morning, the highway was clear and there was little sign of milk in the river.

Information Supplements

This activity requires some knowledge of technical information. Students will learn terms like "nitrates" and "BOD." A short glossary is included, as well as a technical supplement to provide more background information.

The Inquiry

This activity centers on a preliminary investigation conducted by the town council in Oakwood Town Hall. All students take part. Five students will have roles, four more will be the town council, the teacher (or a visitor or a student, if age appropriate) will play the expert, and the remaining students will be concerned members of the public.

The teacher, having access to all the information and knowing the dilemmas of all the participants, may choose to intervene if witnesses seem hesitant to express their true points of view on the situation.

All students will receive copies of the sketch plan of the area, the newspaper clipping, and the Public Inquiry Fact Sheet. In addition, some students will receive special role briefs. Giving students the technical supplement is optional.

The Witnesses

The five characters are members of the community who will be called to testify because of their particular connections to the river. They are:

Sharon or Stanley O'Brien ..... **President of Oakwood Fishing Club**

Jane or John Grant ..... **Co-owner and manager of Meadowbrook Farm**

Gayle or Gordon Grant ..... **Curator of Old Oakwood Mill Museum**

Claudia or Carlos Martinez ..... **Manager of Oakwood Wastewater Treatment Plant**

Mary or Mark Pedersen ..... **Manager of Oakwood Paper Mill**

Materials: These students will receive individual role descriptions, which include some information about the character and examples of conflict of interest.

Instructions: When these students, in their roles as inquiry witnesses, are interrogated by the council members, they should present their perspectives of the problem and be prepared to express an opinion as to the cause of the pollution.

Oakwood Town Council

The town council's task is to determine the likely cause of the fish kill and decide whether further action is needed.

Instructions: The town council should consider the plan, the newspaper clipping, the advice of the expert, and the testimony of the witnesses. After questioning the witnesses and after deliberation, one member of the council will present the results of the inquiry.

The Expert

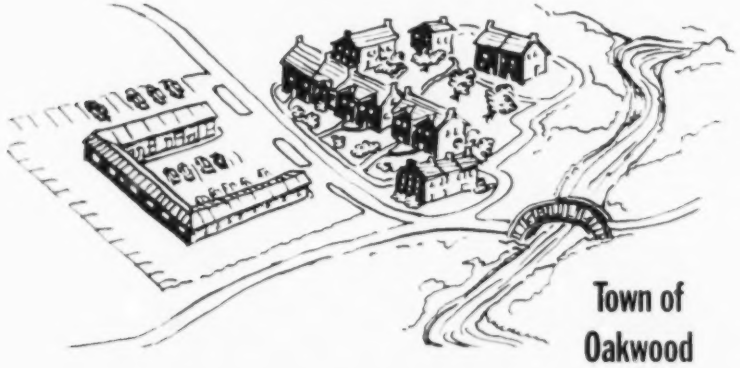
The expert will be available to testify, answer any technical questions that arise, and clarify any points the witnesses make concerning the problems of pollution of the river.

Materials: The expert receives a special role brief. The expert's testimony should be presented at a level appropriate for the class.

Instructions: The expert should be prepared to provide specific information in response to questions from the council members and the public.

The Public

The people of Oakwood attend the inquiry and are encouraged to participate in the proceedings by asking questions of the witnesses and the expert.



The Entire Class: The Debate

Many factors contribute to the increase in nitrates and algae in the river. Students should consider:

- What are all the sources of pollution?
- What are the proposed solutions?
- How should the proposed remedies be evaluated?

Specifically:

- Are the benefits satisfactory?
- Have all the effects of the solutions been determined?
- Are the risks shared appropriately?

Finally, given the complexity of the problem:

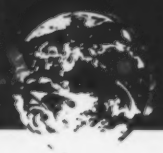
- Is the overall solution coherent?
- Does this solution enable the Stag River to continue to satisfy all its uses (such as water drainage, waste disposal, fishing, recreation, and drinking water for farm animals)?
- Is this solution practical, and will it cause unemployment, higher water fees, or other problems?

The Entire Class: Further Analysis

At the end of the role-play activity, the students can conduct additional activities that will help them interpret what they have learned in the course of the inquiry.

About The Dam

You may wish to explain to students that the small dam raises the water level for the benefit of the Old Mill. The dam does not block the flow of water.



Results of the Inquiry: Sample Answers

After having questioned all the witnesses and heard the public debate, the town council members deliberate and select a spokesperson to present the council's conclusions to the public.

The following is an example of some likely conclusions. (The questions are taken from the Public Inquiry Fact Sheet)

1. Is the river polluted?

YES.

2. Is there a serious problem with poisonous chemicals in the river?

NO. Many invertebrate animals have survived the pollution. There are still fish and ducks in the river.

3. At this stage of the investigation, should the town go to the expense of conducting a complete chemical analysis of the water?

NO. Any chemical pollutants that may have caused the death of the fish have most likely been carried away by the current. An analysis of the water at this point may not reveal any harmful chemicals. The only known local problem with poisonous chemicals has been with chemical substances discharged from the paper mill destroying the microorganisms on the filter beds of the wastewater treatment plant. These chemicals are now disposed of properly, in accordance with government regulations.

4. Is there reason to suspect too much oxygen demand on the water?

YES. Fish kills in slow-moving water at night are often due to high oxygen demand, especially on warm nights. Warm water cannot hold as much dissolved oxygen as cold water.

5. Why have recent fish kills occurred only at Site 1, and why only on warm evenings? (Hint: Look at what is just upstream on the plan.)

There is a farm upstream. Biological analysis of the site shows the presence of midge larvae and water lice, an indication that the oxygen level is low. Some organic farms have runoff containing manure, which has a high biochemical oxygen demand (BOD). Decomposition that uses oxygen occurs more rapidly at higher temperatures. At night, aquatic plants cannot compensate for the oxygen that has been lost.

6. Why have there been no fish kills at Site 2? (See plan.)

When water falls over the dam, it is aerated; oxygen that has been consumed in the decomposition process is replaced. The water at Site 2 flows faster and is shallower, which also helps dissolve oxygen.

7. How would you recommend monitoring the levels of pollution in the river in the future, and what would you expect to find ?

Samples taken at Site 1 should be analyzed to see if there is a high BOD. Dissolved-oxygen levels measured in daytime are normally high, because green algae and submerged plants are producing oxygen as a by-product of photosynthesis. Levels measured at night will be lower. Pollution from the farm can be monitored by examining the animal life in the river.

8. Given all the evidence available at this time, what caused the fish kills in this case?

As is the case with any pollution investigation, it is essential to consider all data. In this case, a story in the newspaper provides a clue to the solution. A milk tanker overturned and the milk was flushed into the river. This was almost certainly the cause of the fish kill that night.

Further Analysis

The following activities may be used to reinforce the learning from the role-play activity. The level will depend on the age and ability of the students.

1. Water Quality ("Conflict of Use" matrix). Water is polluted if it is unsuitable for the use required. Did the inquiry identify all uses of the river? Use the evidence of the inquiry to create and fill in a matrix. (See page 13.)

2. Conflicts and Alliances (relationship diagram). The public inquiry should identify all the people and organizations who have a stake in the Stag River. Draw a diagram to express the relationship among the stakeholders. (See page 14.)

3. Forces For and Against Change (force-field analysis). For students of appropriate age and ability, the technique of force-field analysis may be used without introducing the terminology. Construct a diagram to identify the driving and restraining forces to change. (See page 15.)

4. Public Opinion (group or class discussion). Topic: "The Role of the Media in Influencing Public Opinion."

5. Conflicts in the Use of Resources (group or class discussion). Topic: "Who Should Pay?" Should agriculture and industry bear the cost of cleaning up effluent so that future fish kills are avoided? Should the fishing-club members help pay for clean water? Should the taxpayer be expected to contribute? This topic is an example of a conflict in the use of resources.

1. Water Quality: "Conflict of Use" Matrix

Which uses of the river conflict with others? The following diagram shows some sample categories that are drawn from the role-play activity. Possible categories include Effluent Disposal (wastewater treatment plant, farms), Cooling Water (the paper mill), and Recreation (fishing, the museum's visitor center).

Lead the class in making a chart like the one below and have the students color in the uses.

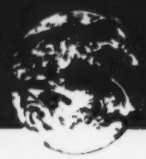
- Compatible Use: Green
- Less Compatible Use: Orange
- Incompatible Use: Red

Note that some uses actually reinforce each other, such as the demands of the fishing club and the museum's visitor center.

Conflict of Use Matrix

	Wastewater Treatment	Cooling Water	Fishing/ Recreation	Farm Runoff	Visitor Center
Wastewater Treatment					
Cooling Water					
Fishing/ Recreation					
Farm Runoff					
Visitor Center					

Green = Compatible Uses Orange = Less Compatible Red = Incompatible

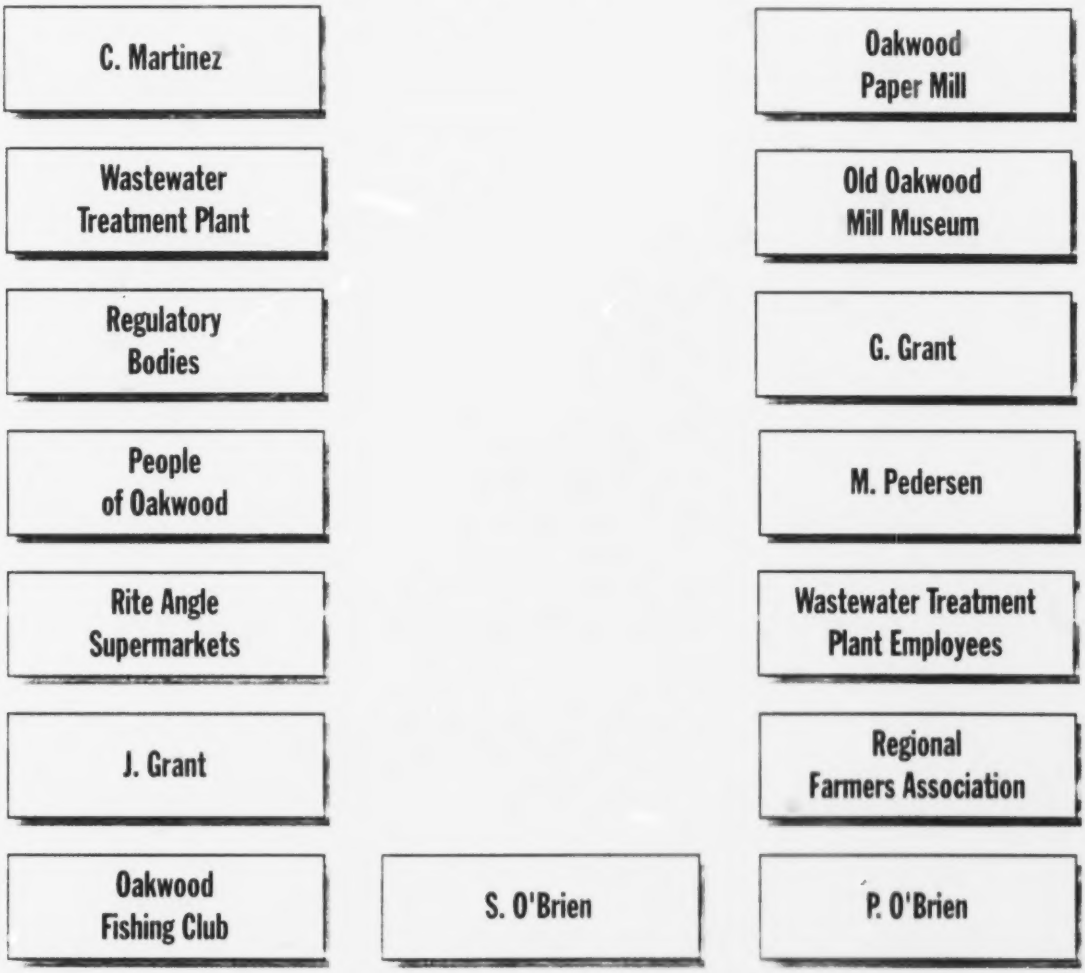


2. Conflicts and Alliances: Relationship Diagram

A visual representation of the relationships between the stakeholders—the people and organizations involved—is useful as a means of exploring the complex situation set up by the role play.

Lead the class in creating a diagram in which each box contains the name of a stakeholder. (The following is an example.) Brainstorm the relationships that exist among the stakeholders and show the relationships by drawing lines between boxes.

Sample Diagram



3. Forces For and Against Change: Force-Field Analysis

Force-field analysis is a third way to communicate, analyze, and document the issues generated by the role-play activity. A simple, non-technical approach to force-field analysis can help make young people aware that problems in the environment can be influenced by the society in which the problems arise and by the extent of the society's resources.

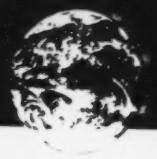
What factors drive or restrain change in this situation? You can think of them in four categories: social, technological, economic, and political (STEP).

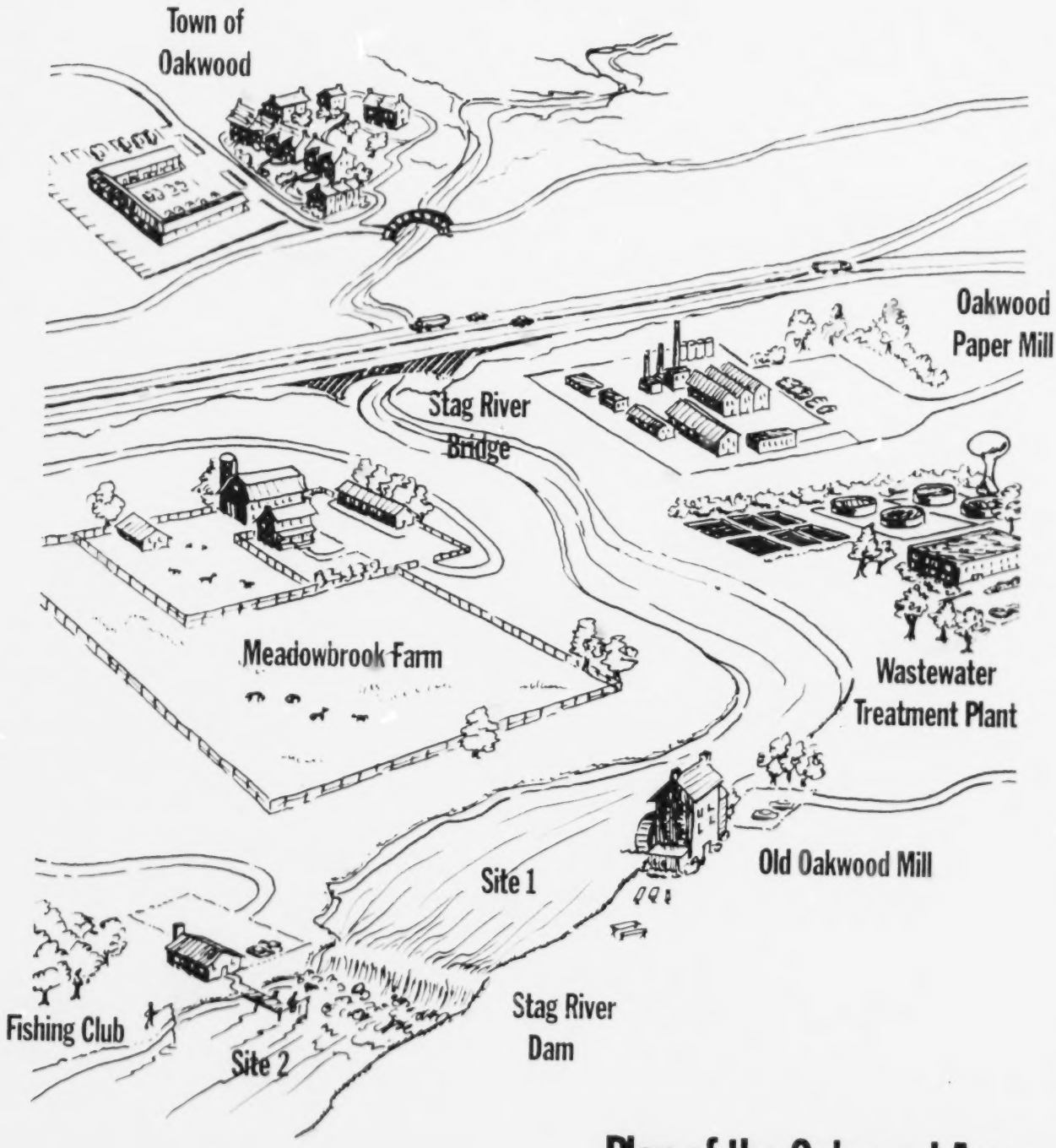
Here is an example of a force-field analysis diagram derived from the role-play activity. An example is given for each heading. Students can discuss other examples.

Factors Driving or Restraining Change

DRIVING FORCES >	< CONSTRAINING FORCES
SOCIAL FACTORS	
Awareness of environmental issues	Threat of loss of jobs
TECHNOLOGICAL FACTORS	
Availability of improved methods of wastewater treatment	Familiarity and comfort with existing equipment and methods
ECONOMIC FACTORS	
Loss of tourist dollars at news of more fish kills	Cost of improving wastewater treatment
POLITICAL FACTORS	
Interest in protecting the environment	Resistance to government spending

ACTIVITY SHEET : CHALLENGE
PLAN OF OAKWOOD





Plan of the Oakwood Area

Clean Water Challenge: A Role-Play Activity

Cast List

Sharon or Stanley O'Brien
President of Oakwood Fishing Club

Jane or John Grant
Co-owner and manager of Meadowbrook Organic Farm

Gayle or Gordon Grant
Curator of Old Oakwood Mill Museum

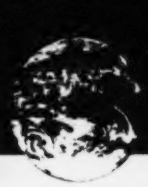
Claudia or Carlos Martinez
Manager of Oakwood Wastewater Treatment Plant

Mary or Mark Pedersen
Manager of Oakwood Paper Mill

The Expert

Town Council Members

People of Oakwood



Role Brief: President of the Fishing Club

You are SHARON or STANLEY O'BRIEN. You are president of the Oakwood Fishing Club and have been a member for 25 years. You are 40 years old and have lived in Oakwood all your life. You work at Oakwood Paper Mill as a machine operator.

You live in a new housing development upstream from Old Oakwood Mill. Since this development was completed, the wastewater treatment plant has reached close to maximum capacity, and you are concerned that untreated sewage may be spilling into the river.

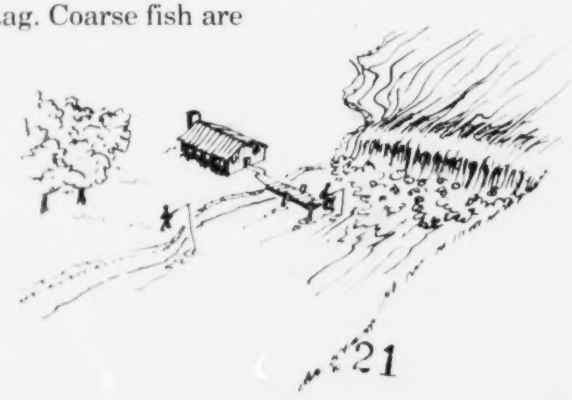
You are married and have two children, Peter, aged 16, and Zoe, aged 7. It is a struggle to pay the mortgage and to keep up with the cost of living. You could not easily afford a large increase in water rates. Peter likes fishing and is a trainee at Meadowbrook Farm.

Fishing on the Stag River

The fishing club uses the Stag River for recreation. Club members catch mostly coarse fish like perch, bream, and carp. The club has had to restock the river several times in the past few years. Last time, it cost 600 dollars.

You and Peter know which types of fish have adapted well to the conditions in the river, which has always supported some plant growth. River weeds have increased in recent years, so they now often choke the main channel, especially in the spring.

You know that game fish like trout could never survive in a river like the Stag. Coarse fish are better adapted to the lower levels of dissolved oxygen found in the river. The situation must be getting very bad now, if even these fish have died.



A Lesson About Nitrates

A television program you saw recently increased your concern about the effect of lowered oxygen levels in the river.

The program explained that extra plant growth occurs when there are lots of nitrates in the water. Nitrates are found in agricultural effluent, when rain washes animal manure and fertilizers into field drains, and into sewage.

The program also showed how bacteria in rotting dead plants (and sometimes in sewage, effluent from paper mills, and organic materials like milk) use the oxygen in the river water. You know that something they called "high BOD" kills fish, but are not sure exactly what BOD is.

Your Knowledge of River Conditions

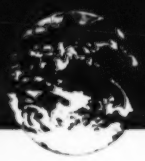
You know that ducks and many invertebrate animals like mayfly larvae are less affected by low dissolved-oxygen levels than fish. Because they have survived, you believe that there was no poison in the water.

You and the other fishing-club members have noticed that fish kills in the Oakwood area often occur before dawn in summer in slow-flowing water. You know that these conditions cause very low dissolved-oxygen levels.

Club members use the dam to help them catch fish. Fish often gather under the dam at night, because the current carries down food such as dislodged insects, and the churning water also keeps the dissolved oxygen at high levels. No fish kills have occurred below the dam.

Your Dilemma

You think that sewage overflow and runoff from fertilizers on farms are causing the problem. But you also worry about the effluent from the paper mill and the runoff of manure from Meadowbrook Farm. You are hesitant to mention these concerns, though, because it might affect your job or your son Peter's.



Role Brief: Co-Owner and Manager of Meadowbrook Farm

You are JANE or JOHN GRANT. You run Meadowbrook Farm, which covers the whole area around Oakwood Dam. You are 45 years old and single, and you own the farm with your mother, two sisters, and a brother. You live in the farmhouse with your mother and sister Gayle (or brother Gordon), aged 30, who is also part-time curator of Old Oakwood Mill Museum.

You took over the farm when your father died nearly 10 years ago. Although you have worked on the farm most of your life, you are also a trained accountant. You are a very competent farmer, but are now mainly involved in running the business aspects of the farm. You are concerned about the environment and are an excellent manager.

Your Accomplishments and Plans

You are proud that for the past 5 years you have run Meadowbrook as an organic farm. It is a very profitable business. You get good prices for supplying the Rite Angle supermarket chain with organic products. You keep up on what the customers want, and produce to demand, where possible. At present, you grow a range of vegetables, raise pigs and chickens, and keep some dairy cows.

You have worked hard to develop the business while following Rite Angle's guidelines and meeting state and local standards for organic produce. Your business objectives are to protect the environment and also to get the best prices.

The farm has five full-time employees, all local people, including Peter O'Brien, 16, who has just started as a trainee.

Your sister Gayle (or brother Gordon), who has worked at the farm part-time since becoming curator of Old Oakwood Mill Museum, is thinking of opening the farm as a tourist attraction. This would include a recreational river walk.

Your Convictions

You have not used artificial fertilizers on the fields in over 5 years. You understand the need to replace the nitrates necessary to grow corn, grain, and vegetables. While other farmers use artificial fertilizers to replace nitrogen taken from the soil, you plant a legume crop such as soybeans or peas in each field every other year.

These plants have root nodules that contain bacteria that can "fix" nitrogen directly from the atmosphere. This method replaces the nitrogen in the soil in a form crops can use.

These are the traditional ways to fertilize the soil that were used before chemical fertilizers were invented. You know that Meadowbrook's yields will not be as great as those of farmers who use pesticides and fertilizers. Your farm cannot compete based on quantity, but you have established a reputation for organic food of excellent quality, for which shoppers will pay more.

Some Concerns

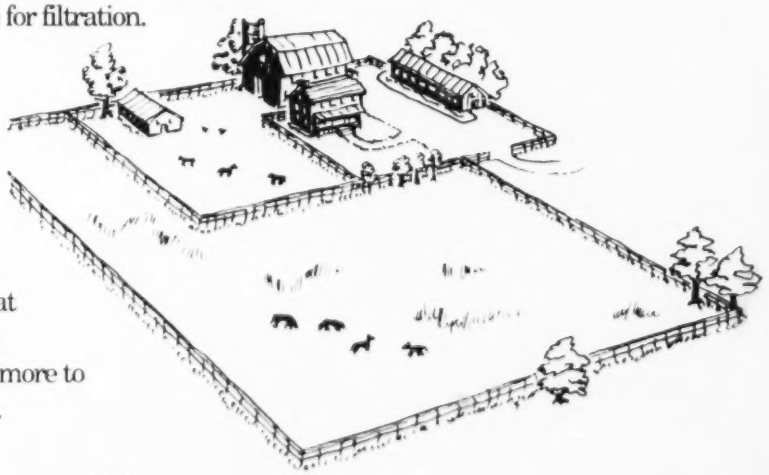
You have been meeting government regulations for discharges from the farm, but you are starting to worry about the runoff of water from the farmyard and fields into the river. It contains manure which has a high nitrogen content, like that of chemical fertilizer; it contributes to the growth of bacteria that use oxygen from the water. It also contains milk washings. You are considering taking more land out of production along the river to serve as a physical barrier to runoff, as well as to provide an area of natural filtration before runoff enters the river.

A treatment plant on the farm would not remove minerals and salts like nitrates, chlorides, and phosphates, which are released when the organic material in the effluent is broken down by bacteria. These chemicals would remain in the water draining to the river and would fertilize river weeds. The weeds would overgrow, choke the stream, die, and rot; oxygen levels would be lowered.

The pigs and cows wander freely and sometimes cool off in the river. Wastes from these animals go directly into the river and therefore do not have any chance for filtration.

Your Opinion

You think that the paper mill is primarily responsible for affecting the water quality of the Stag River, and perhaps also Oakwood Industrial Park, far upstream. You also believe that other farmers upstream who use fertilizers to grow their crops are more to blame than Meadowbrook Farm.



Role Brief: Curator of Old Oakwood Mill Museum

You are GAYLE or GORDON GRANT, curator of Old Oakwood Mill Museum, which is a working mill. You are 30 years old and a co-owner of Meadowbrook Farm, an organic farm, where you work part-time.

You would like to encourage tourism by opening up Meadowbrook Farm to visitors as an extra attraction, which would also help draw people to the museum.

You have a small staff of volunteers, who help run the mill, mostly on weekends. Some travel from quite far away.

The museum's trustees want to make the Stag River an attractive site for recreation to increase the appeal of the mill. This would also help you follow through on your plan to bring tourists to Meadowbrook Farm.

The Stag River Must Remain Attractive

As the representative of the mill's trustees, you need to stress the use of the Stag River as an amenity with visual appeal. You cannot allow the river channel to become choked with weeds, which are smelly and unpleasant. You know that weed growth can be stimulated by runoff of excess fertilizer from fields, farmyard drainage, and sewage effluent.

The Museum Needs Its Sponsors

The trustees have recently spent a lot of money renovating the mill for visitors and adding a picnic area. The money was donated by local residents, companies, and organizations, including the Oakwood Chamber of Commerce, Oakwood Paper Mill, and the Oakwood Regional Farm Association.

You certainly do not want to upset these sponsors, and especially not the paper mill, which you count on to make a donation every year.

You are also anxious to stress that the trustees have been encouraged by local authorities to keep this project moving.

A Conflict of Interest

As a partner in Meadowbrook Farm, you may have to find a large amount of cash to install a treatment plant for farm effluent if the government decides that tighter controls are necessary.

This would mean you would have no money left to invest in developing the farm for tourism, even though you believe the venture would make money in the long run.

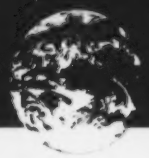
You also know that investment in a treatment plant on the farm might do little to stop the weed growth, even if the farm is at fault. Standard treatment of sewage and farmyard waste usually only breaks down the organic material into salts (such as nitrates) and minerals. These would still enter the river and fertilize the weeds.

Only sophisticated and expensive methods of treatment that also remove the salts and minerals from the treated effluent would fully protect the river from the farm wastes.

Your Concern

Your main problem at Old Oakwood Mill is the toilets; they are not connected to the sewer system but feed into a septic system, which is old and may be overloaded. The cost of installing improved treatment would be beyond the means of the trustees' budget.

Even if funds could be found to connect the toilets to the main sewers, you believe it would not help much, because you have heard that the wastewater treatment plant is already overloaded.



Role Brief: Manager of Oakwood Wastewater Treatment Plant

You are CLAUDIA or CARLOS MARTINEZ, manager of the Oakwood Wastewater Treatment Plant. You are 55 years old and have been running the plant for almost 20 years. You hope to remain in this position until you turn 65 and can retire with a full pension.

You are married and have two grown children, both of whom live in Oakwood and work at the paper mill.

A Borderline Situation

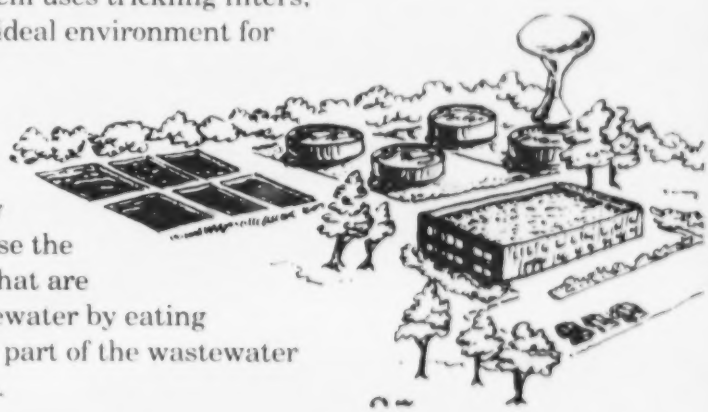
The wastewater treatment plant is at maximum capacity, and you are concerned about it becoming overloaded. Also, the BOD from the plant sometimes exceeds the permitted levels.

This is because the new highway has suddenly made Oakwood popular with commuters, and many new houses have been built. The wastewater treatment plant has not been upgraded in 30 years. In unusual circumstances, there was a discharge of untreated sewage into the river, but the plant was reopened and you believe this is not likely to happen again. The discharge brought many complaints, and the plant is now being very carefully monitored.

Others Could Help

Things would be easier if people were more careful about what they put down the drain.

Lately, it has been hard to keep the plant running properly. The system uses trickling filters, which provide an ideal environment for millions of tiny organisms to grow. These beneficial organisms, mainly bacteria, decompose the sewage particles that are found in the wastewater by eating them. This is only part of the wastewater treatment process.



Last week, you had to close down the plant temporarily, because someone, somewhere, put engine oil down the drain and it got into the sewers. The oil coated the filters and killed the beneficial organisms.

There was a big problem in the past with some chemicals that are used in the laboratories at the paper mill. When these poisonous chemicals were discharged into the water, they killed the organisms that live on the trickling-filter beds. The paper mill had to agree to have the dangerous chemicals hauled away in the future. You believe that this problem has now been solved.

You know that a more sophisticated plant that uses the activated-sludge process would be less affected by some of these problems. There are plans to upgrade the facilities at Oakwood sometime in the future.

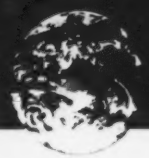
Your Main Concern

You think a new plant will become necessary at some point if they build many more housing developments. But there has been much more development to the south, past Apple Hill. You wonder whether there will really be a need for more housing here in Oakwood. The old hotel has been closed for years. This is a quiet town and has few tourist attractions.

The engineers have already done a study, and the government regulatory bodies are keeping track of the situation. If they decide that a new plant is needed, it should work out fine for you and the other employees.

But the engineer's report outlines an alternative plan to close the plant at Oakwood and pipe the sewage to a newer plant at Apple Hill that still has spare capacity. If that happens, you and your employees may all be out of a job.

This makes you worry about pushing too hard for upgrading the plant at Oakwood.



Role Brief: Manager of Oakwood Paper Mill

You are MARY or MARK PEDERSEN, the manager of Oakwood Paper Mill. You are 39 years old, married, and have two young children. You come from another state and moved to the area for this job. You live in Apple Hill, south of Oakwood.

You are ambitious and have been manager of the paper mill for 2 years now. You really want to become manager of a larger company, which would mean moving away from the area.

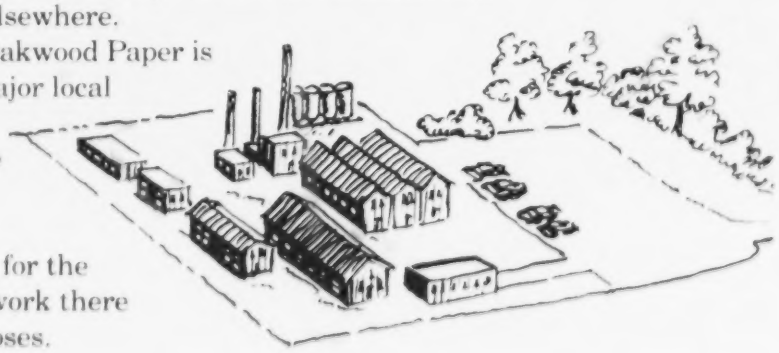
The Owner

Oakwood Paper Mill employs about 120 local people. You were appointed manager when the mill was taken over by the Apex Group from the family that had run the business for more than 80 years.

Apex, a huge, multinational group, will measure your success by the profitability of the mill.

Last year, the new owners installed a small treatment plant to aerate (add air to) the water from the mill before returning it to the river. You feel that if Apex is forced to spend money on any more improvements, they will seriously consider closing the mill and transferring production elsewhere.

Because Oakwood Paper is one of the major local employers, there is little hope of alternative employment for the people who work there if the mill closes.



A Tradition of Goodwill

You have arranged for the paper mill to sponsor the restoration of the Old Oakwood Mill, even though Apex will be judging you only on the profitability of the business.

The past owners of Oakwood Paper have always supported community projects in the village. As manager, you have tried to continue the policy of sponsorship to maintain goodwill in the village. You believe it makes good business sense in the long run.

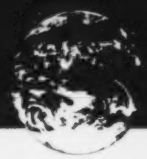
Progress Has Been Made

You know that in the past the paper mill has caused some problems for the river. As far as you know, the high BOD from the paper-washing process has been taken care of by the new aeration plant, which adds oxygen to the water.

Then there are the chemicals from the testing laboratories. Some poisonous chemicals were getting into the drains and affecting Oakwood's wastewater treatment plant. To comply with government regulations that control the discharge of certain chemicals, you had to hire a contractor, who now collects these chemicals and hauls them away to be disposed of properly or recycled.

Present Worries

Now you are worried about the cooling water. The water that is returned to the river may be too warm, especially in summer. As its temperature rises, water cannot hold as much dissolved oxygen. Decomposition occurs more quickly in warmer water; the process uses oxygen, so the amount of oxygen falls just as the oxygen demand rises. Fish die if there is not enough dissolved oxygen in the water. If the problem is the cooling water, you cannot really afford to correct it. Solving the chemical discharge problem has already added to your costs.



Role Brief: The Expert

This role may be played by the teacher, a visitor, or a student. The material should be adapted to suit the needs of the class.

Three Kinds of Water Pollution

There are three main types of water pollution: physical pollution, caused by suspended matter, chemical pollution caused by substances in solution, and thermal pollution caused by an increase in temperature when water is used as a cooling agent.

Pollution from specific points such as factory discharge pipes is called point-source pollution. Pollution from diverse sources, like lawns and farmland, is called nonpoint-source pollution.

Examples of Effects of Pollution

- Changes in the appearance of a river
- Fish kills
- Decline or disappearance of some plant and animal species
- Change in acidity
- Contamination of sediments on the river bottom
- Eutrophication in rivers with slow flow, caused by excess nutrients that promote the growth of algae and certain aquatic plants, and a consequent increase in the consumption of oxygen
- Growth of bacteria caused by the presence of organic matter resulting in increased consumption of oxygen

Assessment and Water Analysis

To interpret a freshwater environment, one must consider all data. Subjective assessment (based on observation), measurements taken at the site, and biological and chemical analyses are all important.

Observation. Site notes, including a plan, are necessary to identify suspected sources of pollution and their locations.

Chemical analysis. Chemical analysis is often used to confirm the exact nature of the pollution, but it can involve

sophisticated sampling and testing. Expensive instruments are required for some tests.

Biological indicators. Living organisms act as useful monitors of conditions in the water. Animals are used as biological indicators to detect pollution, because the sensitivity to chemical products varies by species. The same is true of vegetation. Biological indicator species include midge larvae and water lice. (Organisms that serve as biological indicators are discussed in the Life unit and the Water unit).

Some Observations

• The incident happened on a warm evening. Oxygen is less soluble in warm water. Higher temperatures increase biological activity and raise BOD. Photosynthesis does not occur at night, so oxygen is not replaced then. Only when these factors have combined on warm summer evenings has pollution from the farm depleted the oxygen enough to cause fish kills in the past. These have always occurred at Site 1.

• There was a lot of green algae at the site of the fish kill, which suggested high nitrate levels. A chemical analysis of the water confirmed the presence of nitrates. A full chemical analysis was not performed, but samples taken the next day at two sites revealed low levels of dissolved oxygen and high levels of nitrates.

• Midge larvae and water lice were found at Site 1, an indication of low-oxygen conditions, which could be caused by the presence of an organic substance such as manure.

• Only fish died. Ducks and invertebrates survived. The presence of live animals at the survey site suggests that if poisonous chemicals were ever present, they have been washed away.

• No dead fish were found below the dam (at Site 2), even though there is evidence of a high BOD there. Aeration of the water at the dam promotes oxygenation. The water is also shallower there and flows faster.

ACTIVITY SHEET : CHALLENGE
EXPERT ROLE BRIEF

• Some animal wastes from Meadowbrook Farm are washed directly into the river, without treatment. Even natural effluent such as cow manure will pollute rivers.

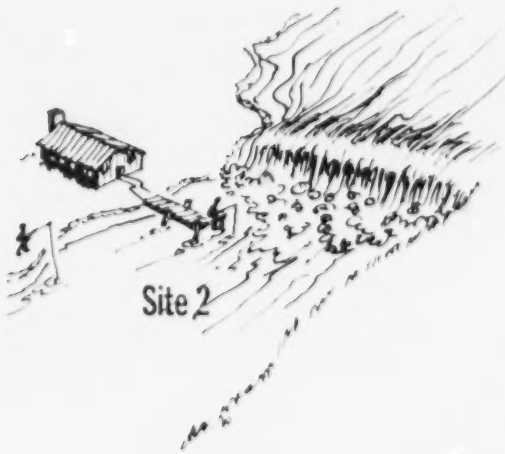
• The opening of the Old Oakwood Mill Museum has resulted in an increase in recreational use of the Stag River. The toilet facilities are not connected to the main sewers: there may be some seepage into the river.

• There was a problem in the past when chemicals discharged from the paper mill killed the beneficial bacteria at the wastewater treatment plant. The mill has now met requirements regulating discharge of point-source pollution. The paper mill, however, still discharges warm water from its cooling system.

• There have been signs of eutrophication of the river in some seasons.

• There are some signs that the wastewater treatment plant may no longer be adequate to support the level of development in the Oakwood area.

• Milk also is a source of water pollution because it has an enormous BOD and also affects the water's acidity. There are several dairy farms in the area, and a milk spill reported in the newspaper occurred on the night before the fish kill was discovered.



Public Inquiry Fact Sheet

The following are some of the questions the Oakwood Town Council will be considering during this investigation. Members of the public will have opportunities to ask questions of the witnesses and to participate in the debate.

1. Is the river polluted?
2. Is there a serious problem with poisonous chemicals in the river?
3. At this stage of the investigation, should the town go to the expense of conducting a complete chemical analysis of the water?
4. Is there reason to suspect that there is too much oxygen demand on the water?
5. Why have recent fish kills generally occurred only at Site 1; why only on warm evenings? (See plan.)
6. Why have there been no fish kills at Site 2? (See plan.)
7. How would you recommend monitoring the levels of pollution in the river in the future, and what would you expect to find?
8. What caused the fish kills in this case?

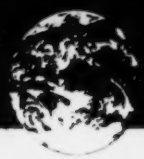
Glossary

Biochemical oxygen demand (BOD). A measure of the amount of organic pollution in water, taken by measuring the amount of oxygen used by microorganisms that decompose organic matter. A high BOD means heavy pollution.

Dissolved-oxygen concentration. The amount of oxygen dissolved in water at any given time.

Eutrophication. The buildup of dissolved nutrients (such as nitrates and phosphates) in a body of water. The nutrients stimulate growth of aquatic plants, which usually causes a depletion of dissolved oxygen.

Nitrates. Salts formed from nitrogen and oxygen, such as sodium nitrate and potassium nitrate.



Technical Supplement

Biochemical Oxygen Demand (BOD)

Microorganisms break down, or decompose, the organic material in water, such as sewage, milk, leaves, and dead fish. During the decomposition process, the microorganisms use oxygen. The more organic material held by the water, the more oxygen will be used. BOD is a measure of the oxygen required to decompose the organic material in the water. An increase in organic material produces a higher BOD and greater pollution.

Dissolved-Oxygen Concentration

The oxygen dissolved in water is used by fish and other aquatic life for respiration. The concentration of the dissolved oxygen is measured in milligrams per liter, or parts per million (ppm).

Levels of dissolved oxygen can fall because of high BOD. Levels of BOD rise during photosynthesis and when the water is rough, causing an increase in the rate of extraction of oxygen from the atmosphere. Warm conditions and high BOD can lead to low dissolved-oxygen levels.

High Nitrate Levels and Eutrophication

Nitrates are one of the main nutrients required by plants for growth. A certain level of nitrate is essential to support the plants that feed the river's animal community, but high levels of nitrates can cause problems.

High levels of nitrates in a body of water will promote the growth of algae and aquatic plants. Long green algal strands in a stream are a good indicator of high nitrate levels. Invertebrates come to feed off the algae, and carnivorous fish eat the invertebrates. When algae and other weeds die, they rot and the BOD increases. High BOD leads to reduced dissolved-oxygen levels, which can cause fish kills.

The loss of oxygen in water due to the buildup of dissolved nutrients like nitrates and phosphates is called *eutrophication* (overfeeding). In rivers with slow flow, the constant depositing of excess nutrients accelerates the growth of algae and some aquatic plants, while damaging

other plants. When algae and plants die, the action of decomposers creates high BOD, and oxygen levels drop.

Nitrates can enter a river in fertilizer runoff from farms. Ammonia compounds in sewage and farm effluent increase nitrates in water through the action of bacteria that use oxygen to transform ammonia to nitrate.

The Natural Process of Water Purification

Natural processes purify the water in rivers and streams. Some dirt settles, and muddy rivers deposit silt. Organisms in the mud feed on dead leaves and other organic material and break up the larger fragments. What is left is broken down further by microorganisms like bacteria and fungi.

These microorganisms use the organic matter as a source of food and energy. In the process of **respiration**, which requires oxygen, they break down the organic matter and convert it to simpler substances, including carbon dioxide and water. In other words, when these microorganisms respire, they cause the **decomposition** of the organic material.

Carbohydrates and fats are broken down to carbon dioxide and water as follows:

Proteins contain nitrogen, and when they decompose, they produce compounds containing ammonia. Bacteria then use ammonia and oxygen to form nitrates and other salts.

If enough oxygen is present, organisms can break down organic matter, even sewage, to produce carbon dioxide, water, nitrates, and a few other salts, like sodium chloride.

The Wastewater Treatment Process

A wastewater treatment plant mimics some of the natural processes that occur in rivers and streams. There are usually two major treatment stages.

In primary treatment, wastewater is held in large **settling tanks** that give heavier solid particles a chance to sink to the bottom. The settled solids (called *sludge*) are removed and treated. The remaining water goes on to the next stage.

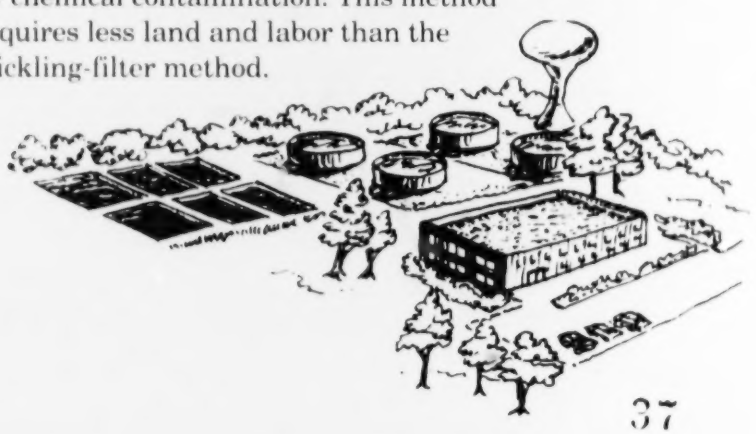
In secondary treatment, the water is aerated (given air) to speed up the natural process of decomposition. Because large amounts of oxygen are available, the natural bacteria are then able to break down the organic matter.

The traditional way to aerate water is to use **trickling filters**. The water is allowed to run over a bed of stones where many beneficial bacteria live. The spaces between the stones allow plenty of oxygen to mix with the water. The sewage waste provides food for the bacteria, which break down the waste as they eat.

Trickling filters contain living communities of organisms. When they work well, sewage is treated with little odor and many harmful bacteria are destroyed.

After aeration, chlorine is usually added to the water to kill the remaining bacteria.

Most larger communities use the **activated-sludge process** instead of trickling filters. The sewage is placed in aeration tanks with beneficial bacteria, and air is blown through the tanks using pumps. This method is more expensive than trickling filters, but it is also less affected by chemical contamination. This method requires less land and labor than the trickling-filter method.



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